MOISTURE AND FOOD CHARACTERISTICS

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One of the primary attributes of quality and acceptability of foods in general, and of dehydrated military rations in particular, is the water of the food in its interaction with other components (proteins, carbohydrates, lipids, etc.) and with the environment. It is not only the absolute amount, but also the physico-chemical state in which water exists (bound, free, in crystalline form, etc.) which affects quality.

One of the best ways to consider the above interactions is the relationship between the absolute amount of water, or percent moisture, and the corresponding relative humidity of the environment, or the water activity, A_w, of the food. This relationship is exemplified by the moisture sorption isotherm, with which most of you are familiar.

In this paper we will consider isotherms for different types of food ranging from very dry to the completely hydrated, or fresh state, drawing mainly on our own inhouse experience, and only to a limited extent on the rather extensive literature which exists on the subject (cf. Labuza et al., 1970, Rockland 1969).

Low Moisture Foods: Foods in this category which are important to the military are usually dehydrated between 0 and about 0.35 Aw. As an example, in this category belongs the Long-Range Patrol Packet. The entree or freeze-dried component of the meal is usually consumed after complete rehydration, but it can also be eaten in the dry state, e.g. like popcorn.

A few years ago, the prevailing theory was that the drier the food, the more stable it is upon storage. It was after the pioneering work of the U.S.D.A., NLabs Food Laboratory, Massachusetts Institute of Technology, General Foods Corporation, and other research centers that this theory was modified as follows:

A certain amount of water in the food may actually be protective against oxidation of lipids. Discussion of the mechanisms of this protective effect is outside the scope of this talk. One can find a description of the different theories in the scientific literature (cf. Maloney et al., 1966).

In other cases the evidence suggests that, under certain conditions of temperature and headspace atmosphere, the presence of water may cause, or be associated with, ascorbic acid destruction, amino-carbonyl browning, protein denaturation as evidenced by a decrease in ATPase activity, protein oxidation, prophyrin pigment changes, fat hydrolysis and other alterations. In contrast to the "antioxidant" effect on lipids, these studies suggest that increasing water content actually promotes protein oxidation. This problem needs a more comprehensive investigation.

Figure 1 shows the oxygen which remains in the headspace of freeze-dried peas packaged under atmospheric conditions, versus weeks of storage at 43.3°C at different relative humidities. At 11% RH, a substantial amount of oxygen is picked up or consumed by the food, in comparison to the zero and 1% RH. At the higher 33 and 50% RH after 10 weeks of storage, the oxygen has been practically depleted. But this alone will not tell us how good or how bad the food is. Here we need the consumer. Figure 2 is a schematic representation of the condensed sensory flavor profile of the same samples examined after 84 days of storage at 43.3° C (Kapsalis et al., 1971). The area of the semicircle represents the amplitude, which is a numerical expression of how complete, how representative and balanced are the typical flavor notes of the food. The radiating lines represent the individual flavor notes, and the degree to which they stand out is represented by the extension beyond the perimeter of the semicircle. A progressive loss of amplitude occurred between 0 and 50% RH. With regard to the individual flavor notes, considering as an example the typical "green pea" flavor, there is a decrease in intensity at 30% RH, and complete loss at

50% RH. At the same time undesirable notes appear, such as the "scorched pea" due to amino-carbonyl type of browning.

It is not only the flavor but the nutritional value which can be affected by moisture, as shown in Table I. With regard to the thiamine, good retention at 43.3° C was exhibited between 0 and 23% RH. In contrast, the carotene content was adversely affected by dry conditions: Minimum retention was shown at 0% RH, while higher retention was evident between 11 to 50% RH. This indicates the protective role of water against oxidation of lipids. The comparison of results of percent retention at 0 and 33% RH at 43.3° C between thiamine and carotene represents a typical example where the water may simultaneously exercise an adverse and favorable role in food stability, depending on the particular component involved.

In addition to the flavor and nutritional changes, the color and appearance characteristics may be affected by moisture as shown in Figure 3 in terms of chlorophyll changes. A drop in the "chlorophyll stability index" (from positive to negative) indicates loss in green color (Kapsalis et al., 1965). There are relatively small changes between 0 and 11% RH, but serious deterioration takes place at the higher RH for the sample stored at 43.3° C. Note that the effect of moisture depends closely on the temperature of storage. At 21.1° C there is very little chlorophyll loss up to the highest RH (50%).

An important consideration with regard to the moisture, is the effect on the mechanical texture properties of foods consumed in the dry state. The detection of mechanical texture changes depends on the type of test which is used (Figure 4). When precooked freeze-dried beef samples are compressed to a very slight extent (about 5%), and the fundamental mechanical or rheological properties are measured, one can see an increase in toughness (work of compression), rigidity or stiffness (apparent modulus of elasticity), swelling, force required to compress the food per unit area of the surface (stress), and brittleness or frictional loss upon compression (crushability index) at about 0.20 Aw.

It is not only the mechanical properties, but also the sensation of dryness which is influenced by the residual moisture in the food, as shown in Figure 5. When the material is extremely dry, the heat which is released in the mouth during rehydration is quite high, whereas at 66% RH the heat is considerably less (Kapsalis et al., 1970a).

Intermediate Moisture Foods: These foods may be dehydrated over a wide range of relative humidity from about 70% to the state of complete hydration. Since it will be the subject of another presentation, I will limit myself to the effect of RH or Aw on the mechanical properties. Figure 6 shows that a maximum of hardness (force of cutting) occurs at about .75 Aw for pre-cooked freeze-dried beef (Kapsalis et al., 1970b). These effects are important in the selection of the best range of moisture, in order to achieve not only optimum sensory flavor characteristics, but also desirable textural properties. They form a basis, where the effects of glycerol and other additives on texture can be studied.

Fresh Foods: Figure 7 shows the changes in the modulus of elasticity as a measure of stiffness (probably "crispiness") which occurs in (A) celery stalks, (B) carrot roots, (C) apple, and (D) potato in relation to the exposure of small, thin slices of each food to the ambient conditions of 21.1° C and 40% RH. Progressive loss of moisture causes a decrease in the turgor properties of the sample which, after a certain time, may be experienced as wilting or staleness (Kapsalis et al., 1972).

Moisture Sorption Hysteresis: This refers to the difference between the adsorption and desorption branch of the isotherm as shown in Figure 8. The area within these branches is called the "hysteresis loop" and it is expressed in terms of the difference between desorption and adsorption in Figure 9 (Wolf et al., 1972). There is a general increase in the area of the hysteresis loop upon storage, and definite differences in the range of Aw where hysteresis extends, for beef, carrots, and haddock. No appreciable

changes occur in potato. These differences could probably be used in combination with other tests as an index of stability, and hopefully, as a basis for predicting the remaining shelf life. Research in this direction is in progress in our laboratory.

Summary and Conclusions: The quality characteristics, such as flavor, texture, nutritional value, and color of foods are markedly affected by the water in the food, within the low and intermediate moisture ranges, as well as in the completely rehydrated and fresh conditions. Every food is "a universe of its own kind" which needs to be investigated in order to determine the optimum moisture conditions for maximum shelf life and acceptability.

<div align="center">REFERENCES</div>

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Table I. Effect of RH on Thiamine and Carotene Content of Freeze-Dried Green Peas, Stored at 21.1°C and 43.3°C for 84 Days

| | Thiamine* | | | | Carotene* | | | |
| | 21.1°C | | 43.3°C | | 21.1°C | | 43.3°C | |
% RH	mg/100g	% retention	mg/100g	% retention	mg/100g	% retention	mg/100g	% retention
0	1.46	97	1.50	100	0.76	37	0.74	36
5	1.49	99	1.50	100	0.88	43	0.82	40
11	1.45	96	1.45	96	1.36	67	0.98	48
23	1.49	99	1.42	94	1.46	72	1.00	49
33	1.34	89	1.22	81	1.66	82	1.00	50
50	1.36	90	0.74	50	1.65	81	0.95	47

*Initial content: thiamine 1.50 mg/100g, carotene 2.03 mg/100g
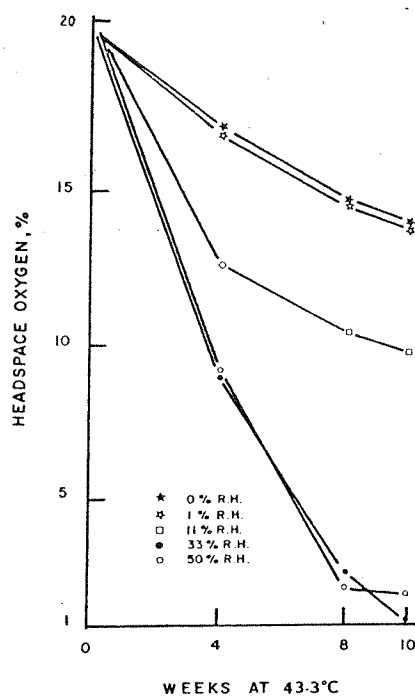
Figure 1. EFFECT OF RH ON HEADSPACE OXYGEN CONTENT OF FREEZE-DRIED PEAS
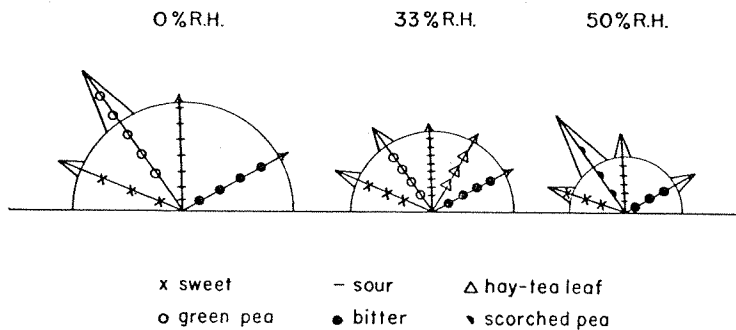
Figure 2. CONDENSED FLAVOR PROFILES OF FREEZE-DRIED PEAS AT DIFFERENT
RELATIVE HUMIDITIES AT 43.3°C AFTER 84 DAYS
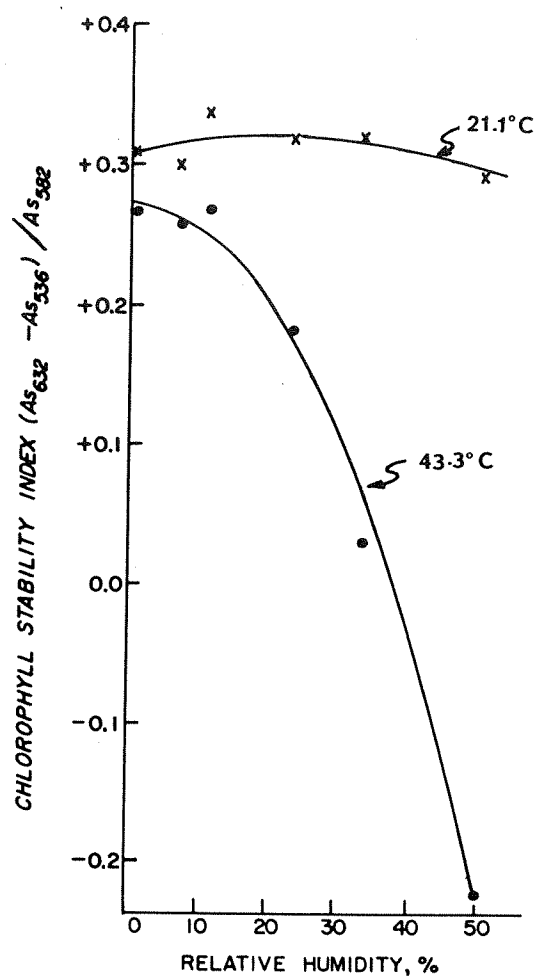
Figure 3. Effect or RH on Chlorophyll Stability of Freeze-dried Peas,
21.1°C and 43.3°C, 84 Days
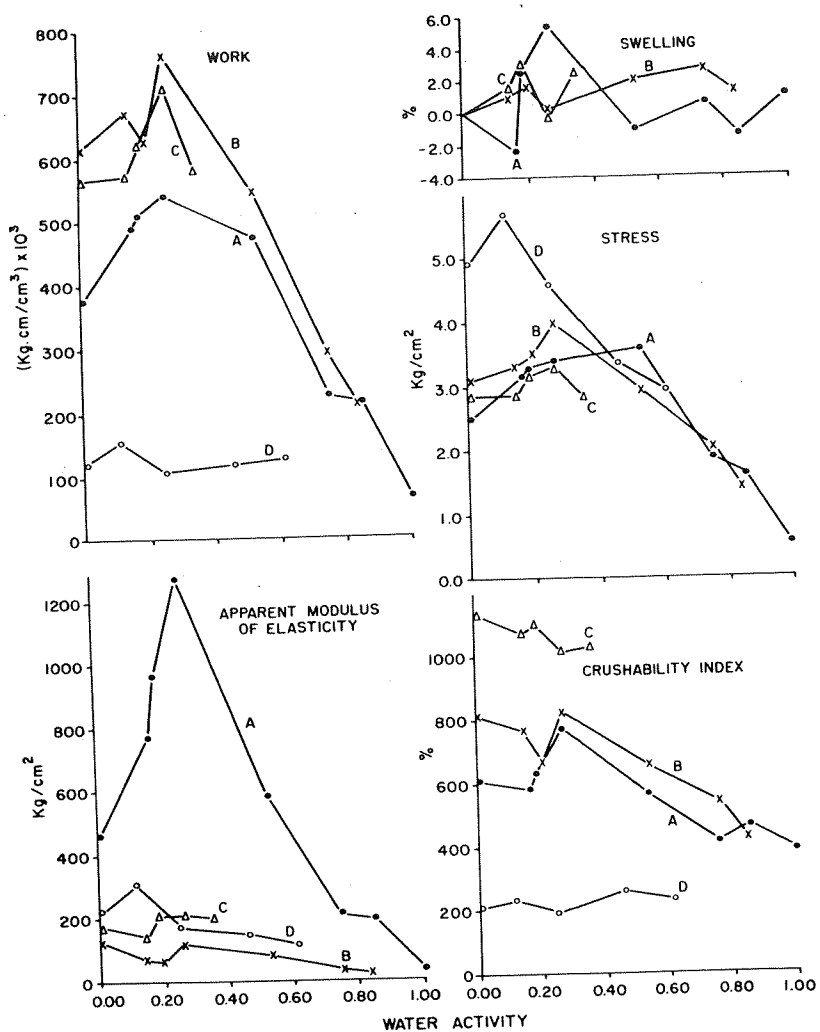
Figure 4. Effect of Water Activity on the Mechanical Properties of Pre-
cooked, Freeze-dried beef. A, B, C, D = Different Samples.
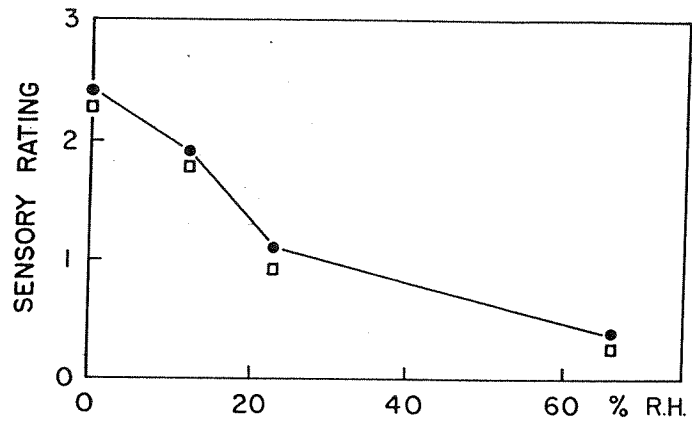Tests by the Instron Universal Testing Apparatus

Figure 5. EFFECT OF RELATIVE HUMIDITY ON THE SENSORY HEAT RELEASED IN THE
MOUTH DURING HYDRATION OF PRE-COOKED, FREEZE-DRIED BEEF. □, ● =
DIFFERENT ANIMALS, 3 = VERY EVIDENT, 0 = NONE
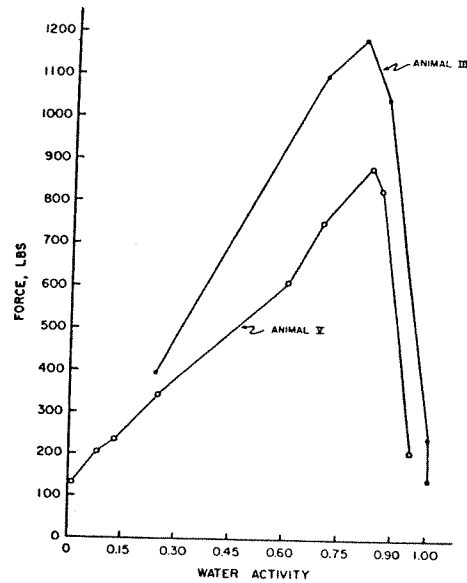
Figure 6. EFFECT OF WATER ACTIVITY ON THE CUTTING FORCE VALUE ("HARDNESS") OF
PRE-COOKED, FREEZE-DRIED BEEF IN THE INTERMEDIATE MOISTURE RANGE.
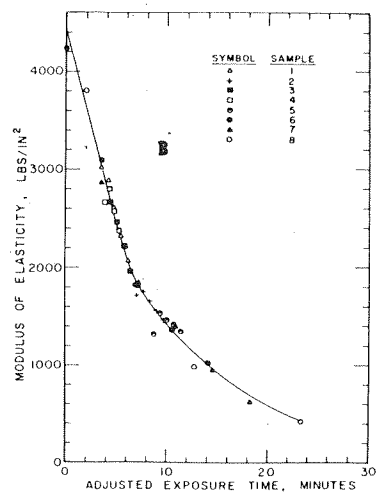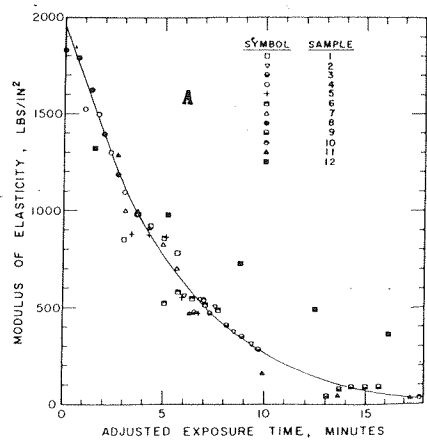TESTS BY THE ALLO-KRAMER SHEAR-PRESS.
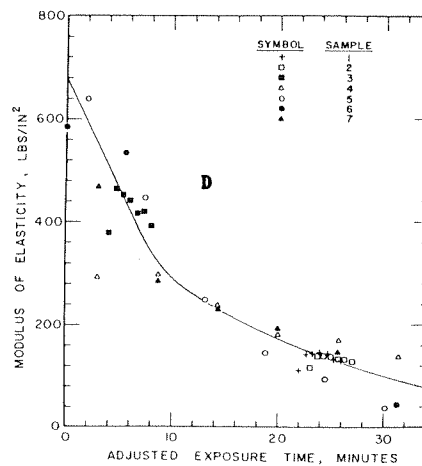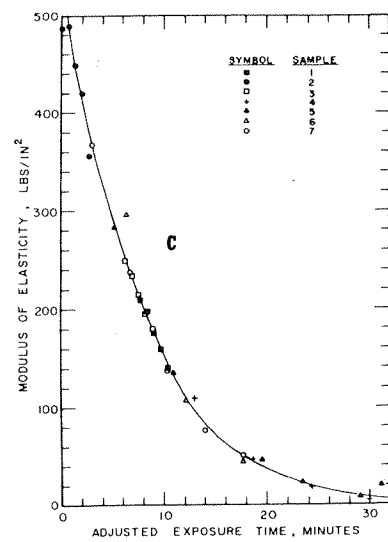
Figure 7. Plots of Adjusted Exposure Time (Including Preparation Time) <u>Versus</u>
Modulus of Elasticity; A, Cellery Stalks; B, Carrot Roots; C, <u>Single</u>
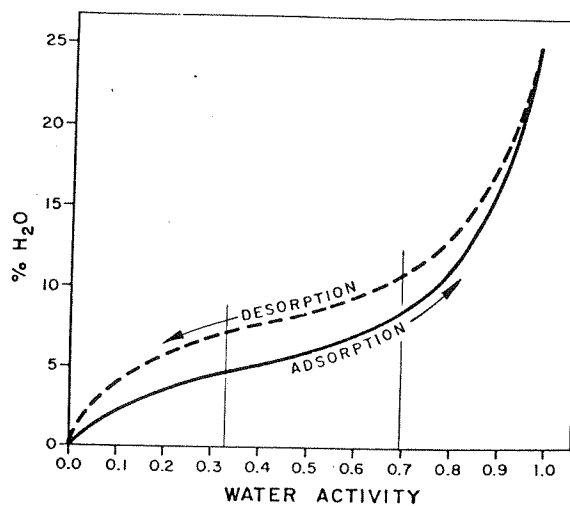Apple (McIntosh, Late Season); D, Potato Tubers.

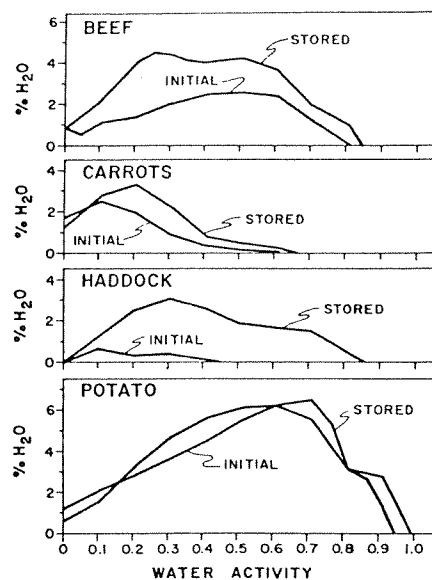Figure 3. MOISTURE SORPTION HYSTERESIS OF A FOOD PRODUCT

Figure 9. CHANGES OF MOISTURE SORPTION HYSTERESIS UPON STORAGE. (ORDINATE INDICATES THE DIFFERENCE BETWEEN DESORPTION AND ADSORPTION)